Ocean Color Experiment Ver. 3 (OCE3)

~ Concept Presentations~

Thermal

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Thermal Requirements

Component	Operating (˚C)	Stability, Operating (˚C)	Survival (˚C)
1 km Red CCD	20	±1	-120 to 70
1 km Blue CCD	20	±1	-120 to 70
250 m VIS CCD	20	±1	-120 to 70
Silicon PIN Photodiode (21)	20	±1	-60 to 70
Silicon PIN Preamp, FET switches/driver (21)	20	±1	-60 to 70
Singlet Preamp (3)	20	±1	-60 to 70
InGaAs PIN Photodiode (48)	-20	±1	-60 to 70
InGaAs PIN Preamp, FET switches/driver (48)	-20	±1	-60 to 70
Singlet Preamp (3)	-20	±1	-60 to 70
Fiber Optics (69)	25	±5	-60 to 70
Digitizer Electronics Box	-10 to 40	N/A	-20 to 50
Main Electronics Box	-10 to 40	N/A	-20 to 50
Mechanism Control Electronics Box	-10 to 40	N/A	-20 to 50

Thermal Requirements

Component	Operating (˚C)	Survival (˚C)
Scan Telescope Assembly	0 to 30, (±5)	-60 to 70
Scan Drum Motor	-10 to 50	-60 to 70
Half Angle Mirror Motor	-10 to 50	-60 to 70
Half Angle Mirror Assembly	-10 to 50	-60 to 70
Momentum Compensation Motor/Resolver	-10 to 50	-60 to 70
Momentum Compensation Wheel	-10 to 50	-60 to 70
Calibration Target Stepper Motor/Resolver	-40 to 50	-60 to 70
Tilt Mechanism Motor/Resolver 1 and 2	-40 to 50	-60 to 70

Power Dissipation: Detectors and Electronics

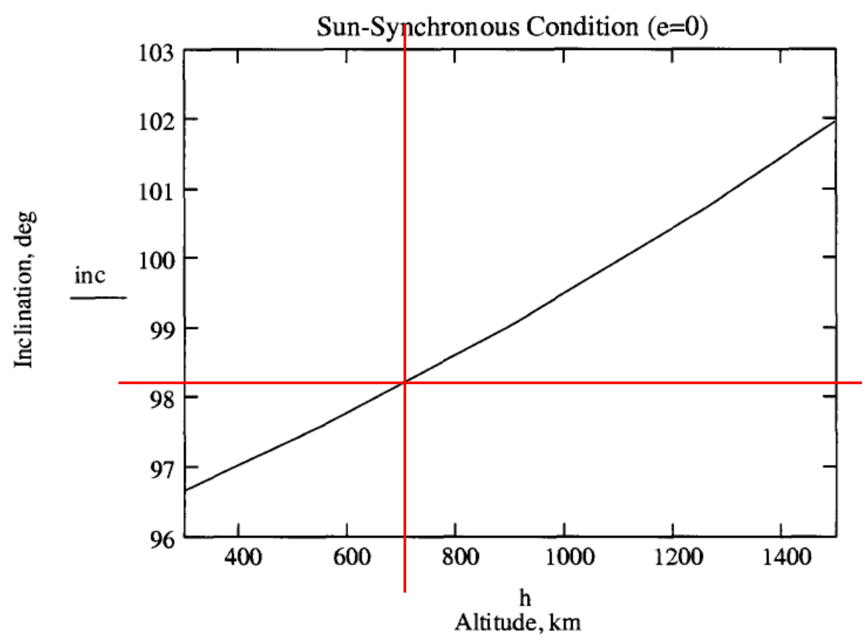
Component	Power Dissipation (W)
1 km Red CCD	0.135
1 km Blue CCD	0.135
250 m VIS CCD	0.135
Silicon PIN Photodiode (21)	1 nW each
Silicon PIN Preamp, FET switches/driver (21)	1 each
Singlet Preamp (6)	1 each
InGaAs PIN Photodiode (48)	1 nW each
InGaAs PIN Preamp, FET switches/driver (48)	1 each
Fiber Optics (69)	0
Digitizer Electronics Box	92
Main Electronics Box	127.4
Mechanism Control Electronics Box	15 average

Power Dissipation: Mechanisms

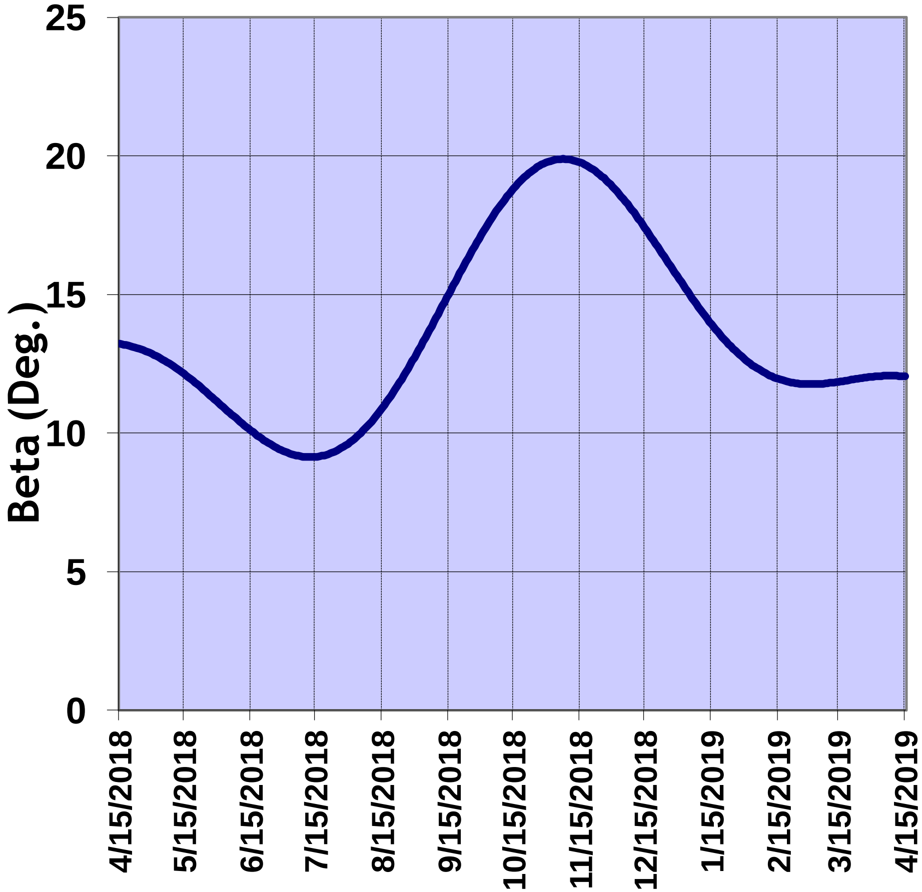
Component	Power Dissipation (W)
Scan Drum Motor	3.8
Half Angle Mirror Motor	0.3
Momentum Compensation Motor	15.4

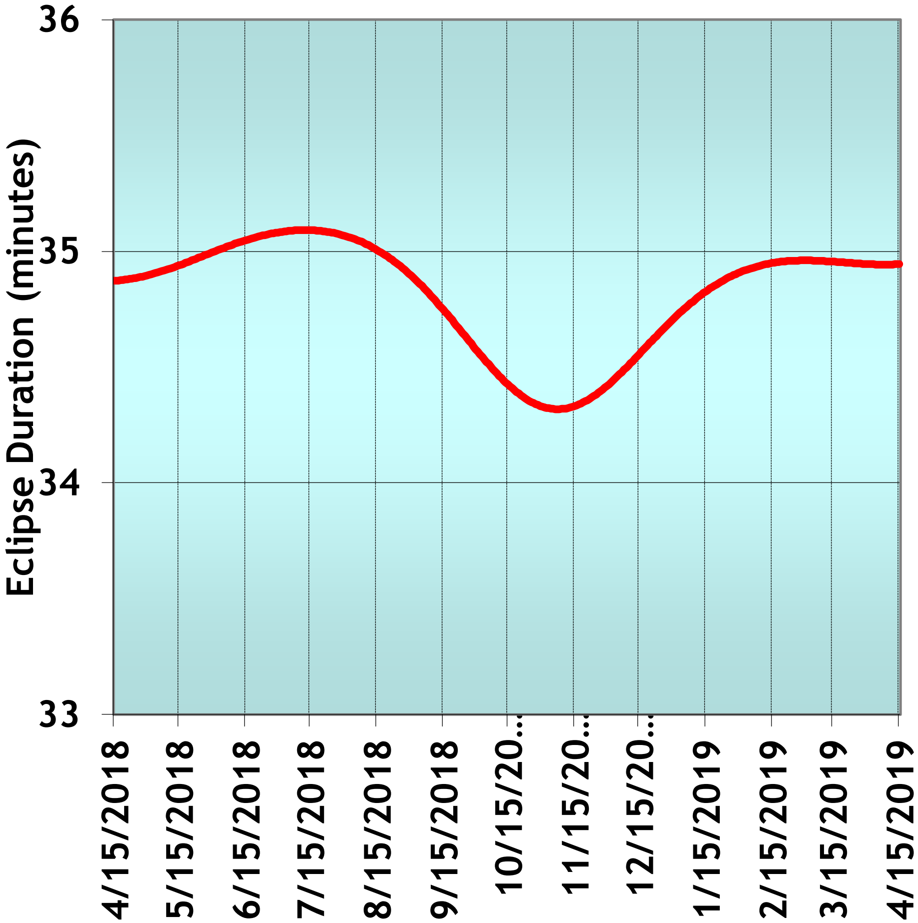
Orbit Parameters

- **Sun synchronous, near-polar, near-circular orbit**
  - Crossing equator at 1100-1300 local time
  - 700 km altitude
- **98.16° inclination**



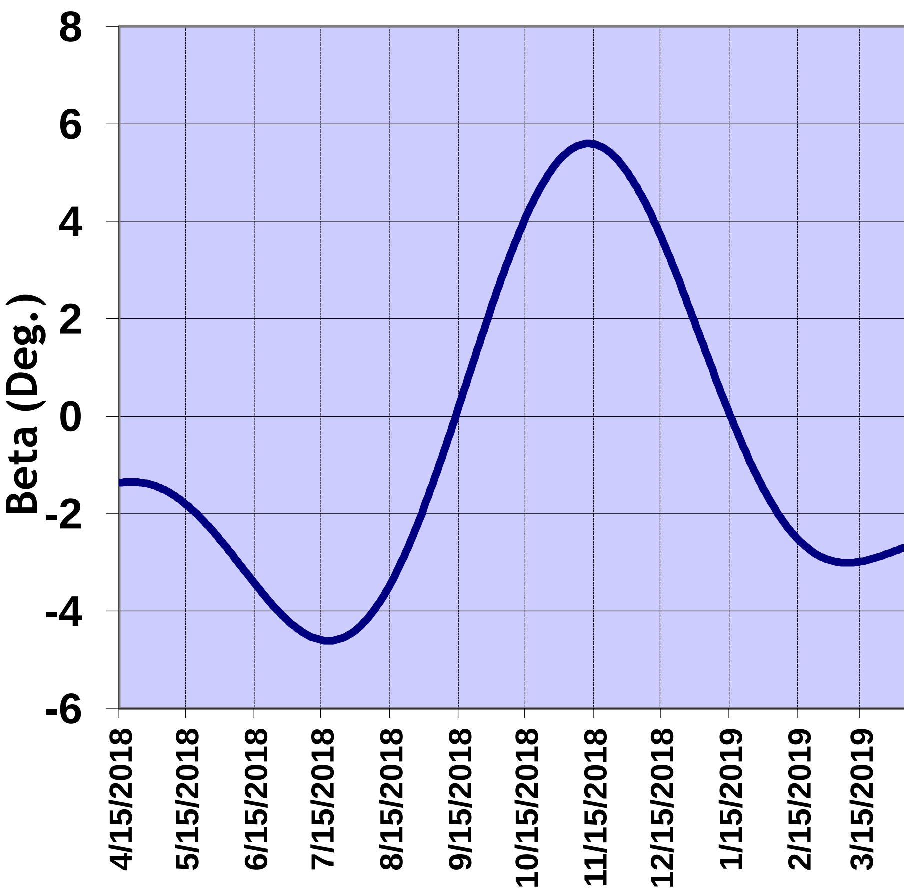
Beta Angle and Eclipse: 1300 Equatorial Crossing

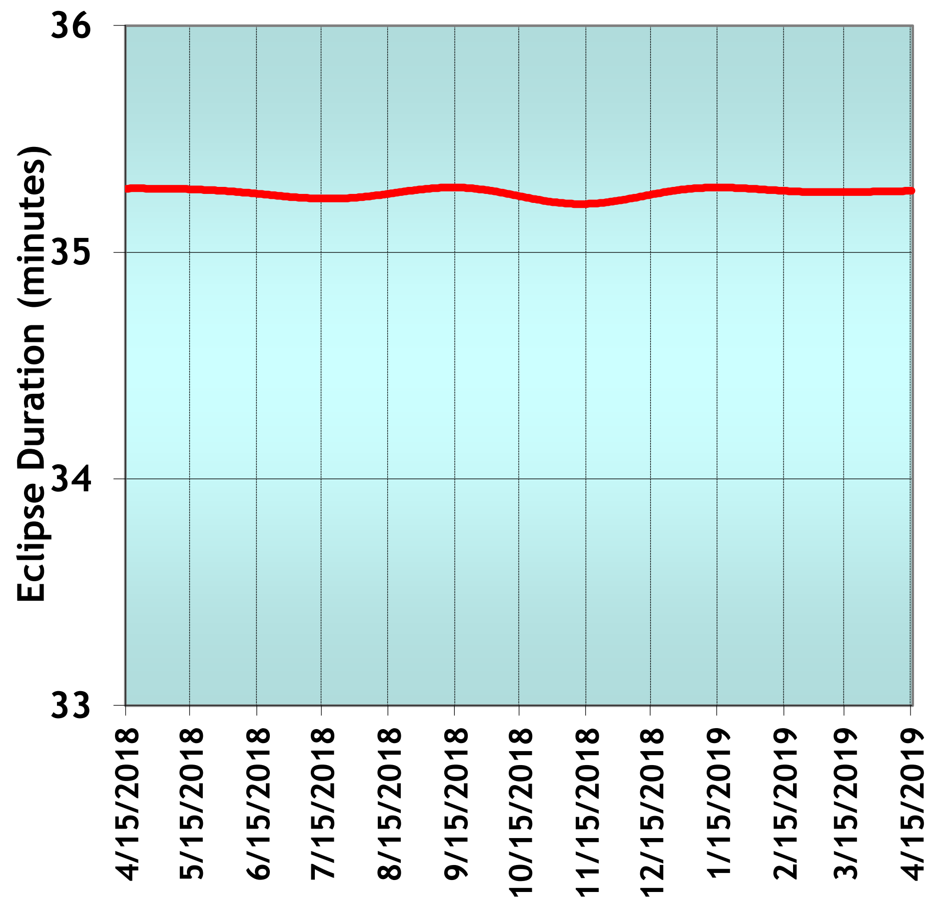




Beta Angle and Eclipse: 1200 Equatorial Crossing

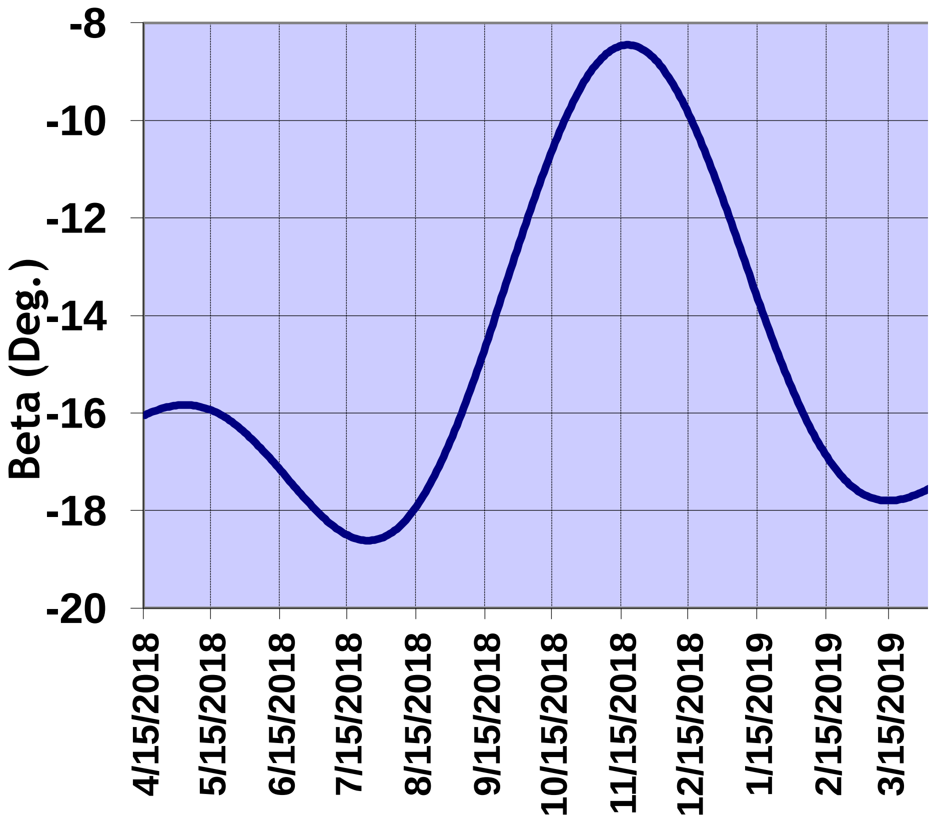
Integrated Design Capability / Instrument Design Laboratory

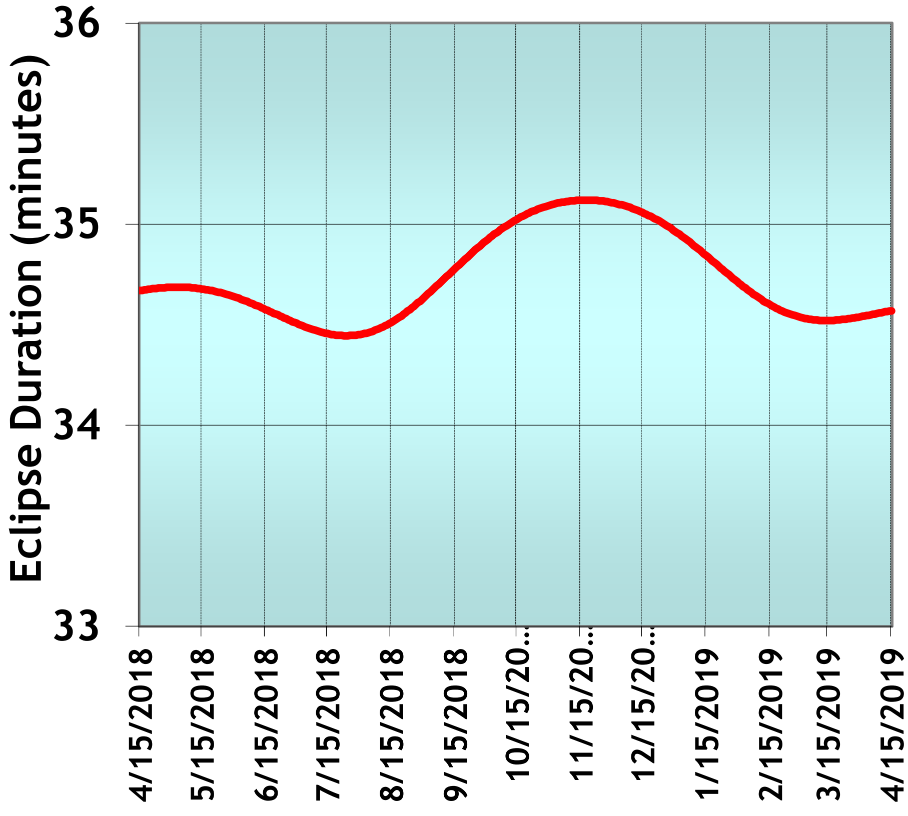




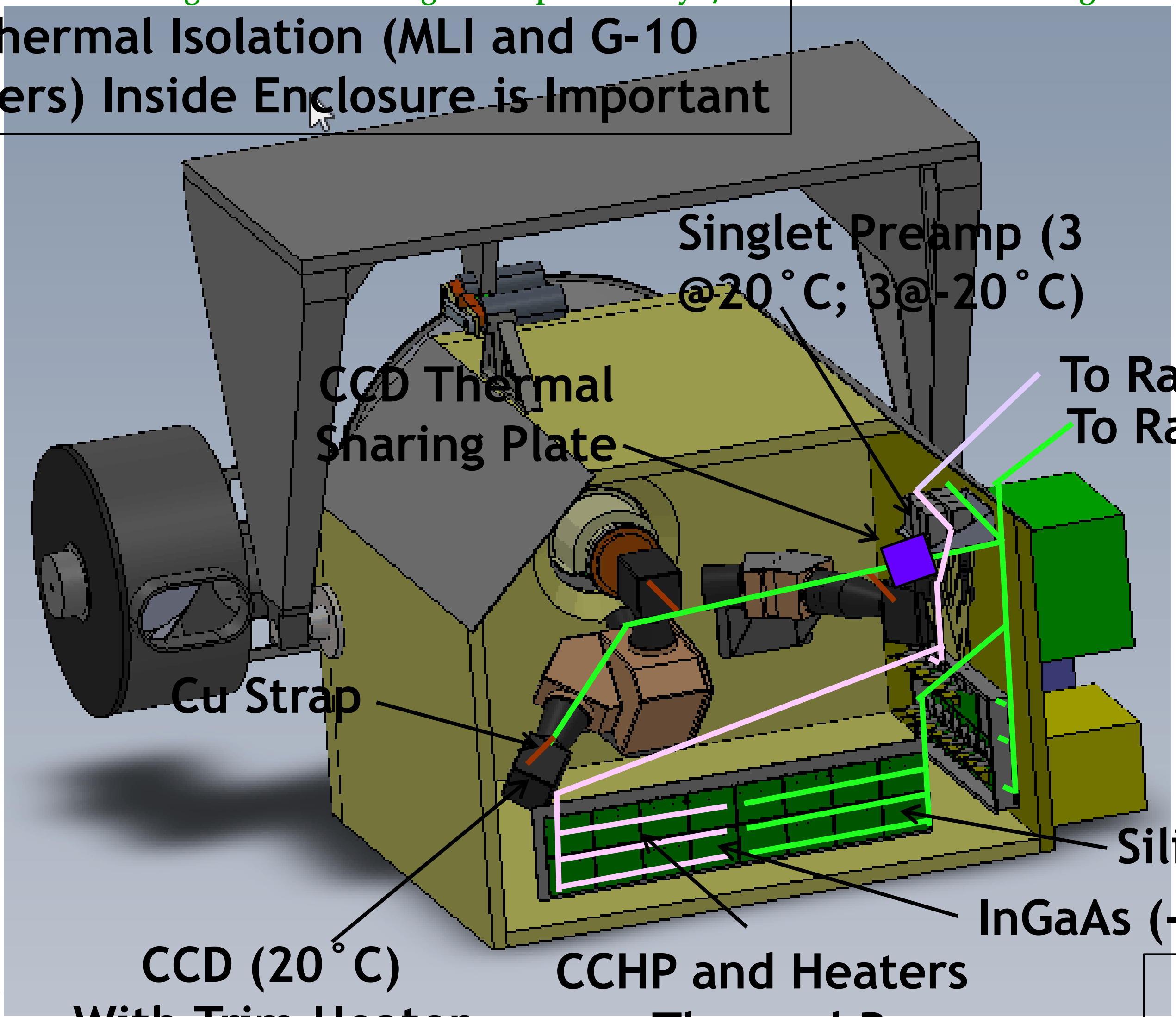
Beta Angle and Eclipse: 1100 Equatorial Crossing

Integrated Design Capability / Instrument Design Laboratory





Photodiode and CCD Thermal Control

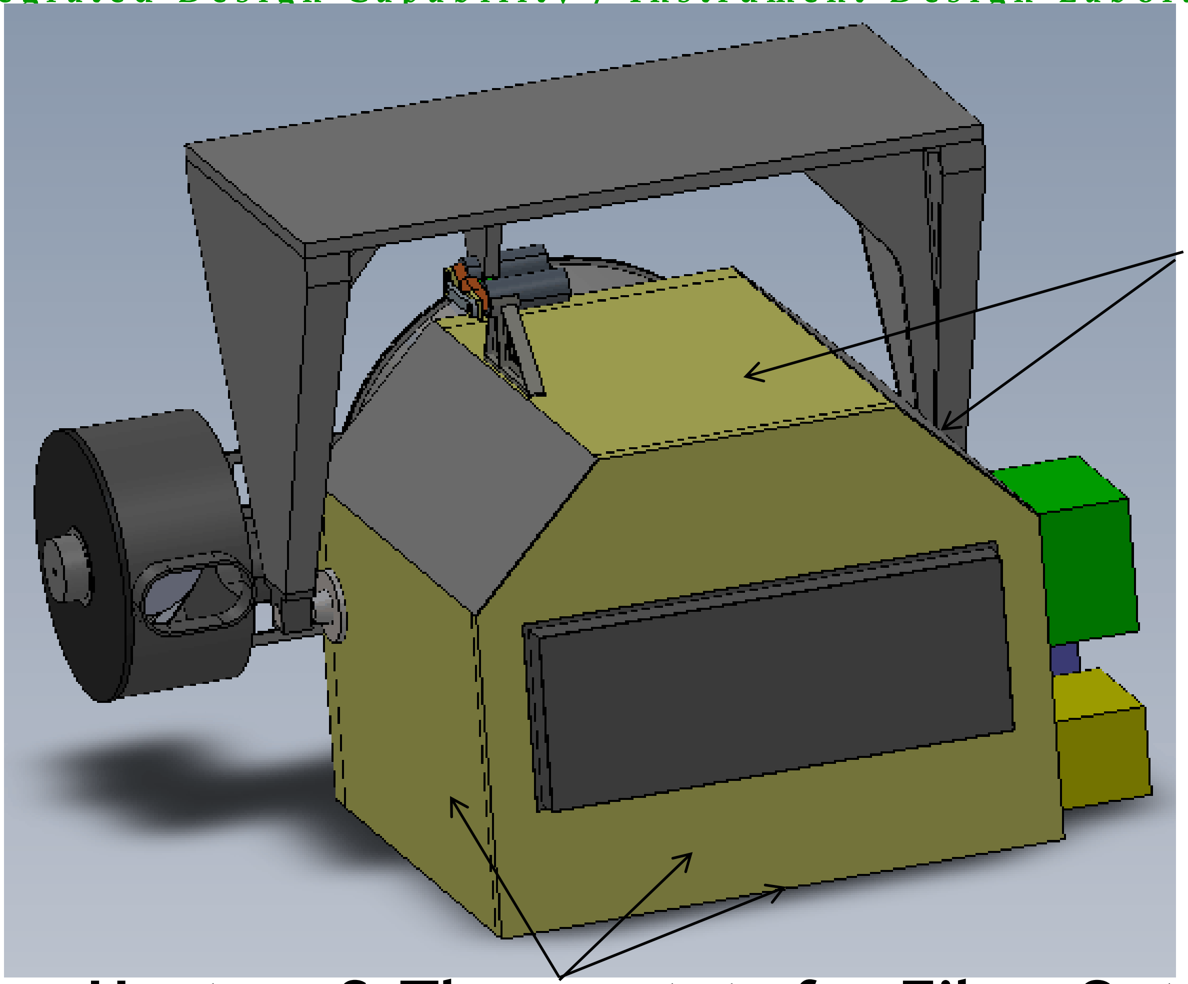


Gravity in Ground Testing (CCHPs in Reflux Mode)

Radiators on Cold Side of S/C)

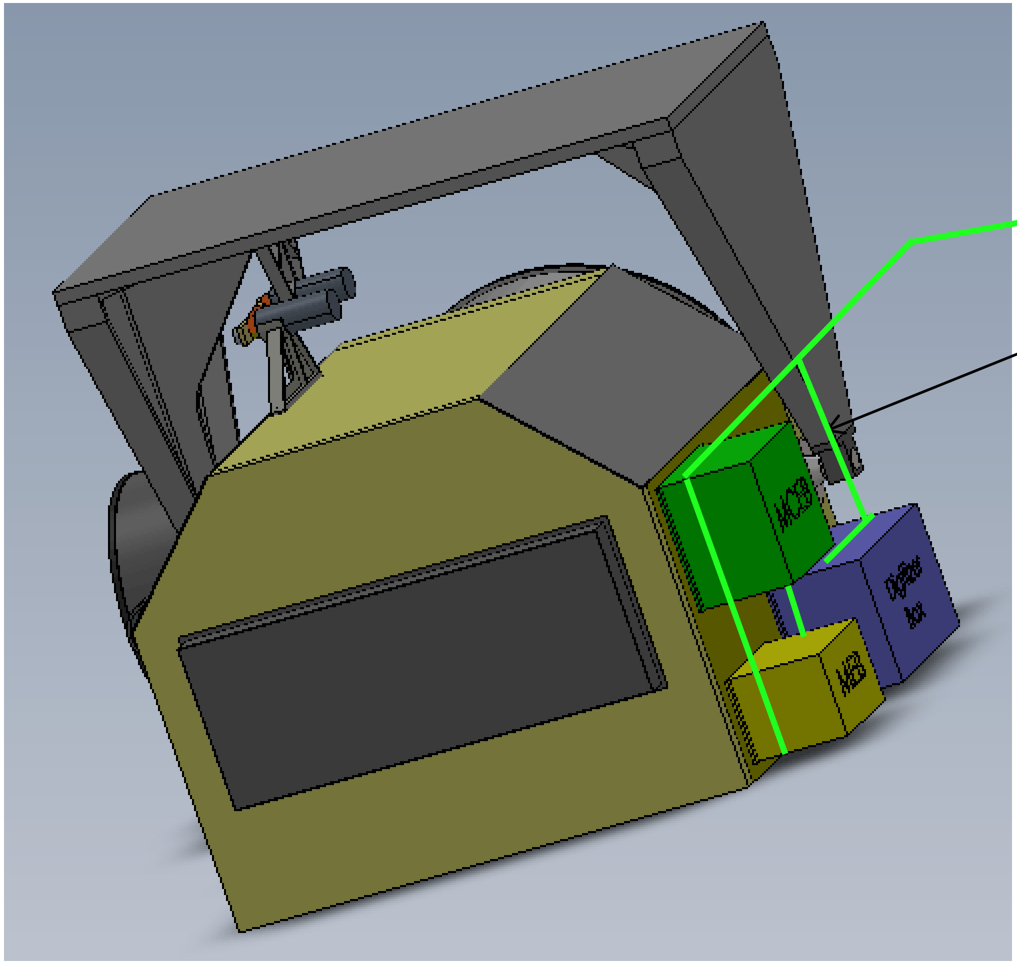
Outgas Heaters

Fiber Optics Thermal Control



Heaters & Thermostats for Fiber Optics Enclosure Which is Covered with MLI

Electronics Boxes Thermal Control



Radiator on Cold Side of S/C

To Radiator

CCHP

Gravity in Ground Testing

(CCHPs in Reflux Mode)

Scan Drum and Fore Optics/Telescope Thermal Control

- **Scan drum and fore optics/telescope thermally isolated from optical bench**
- **AZ93 white paint on exterior and Z306 black paint on interior**
  - Z306 has a 0.96 solar absorptance and is a popular coating for telescopes to minimize stray light
    - Needs bakeout to meet outgas criteria
  - Other black coatings may be considered
    - MS94B silicate black paint absorbs moisture and release it in orbit
    - Black anodize thermo-optical properties vary with its thickness and surface finish

Operating Mode Heater Circuits with Electronics Heater Controller

	# of Primary Heater Circuits	# of Redundant Heater Circuits	# of Thermistors in Primary Heater Circuits	# of Thermistors in Redundant Heater Circuits
Silicon PIN & Preamp Thermal Boxes	8	8	2	2
InGaAs PIN & Preamp Thermal Boxes	9	9	2	2
CCD (3) Thermal Plate*	4	4	1	1
Singlet Preamp Thermal Boxes	9	9	2	2
Total	30	30	7	7

*Reduces number of circuits from 3 to 1 to minimize number of MEB boards

Operating Mode Heater Circuits with Mechanical Thermostats

	# of Primary Heater Circuits	# of Redundant Heater Circuits	# of Thermostats in Primary Heater Circuits	# of Thermostats in Redundant Heater Circuits
Fiber Optics Enclosure	10	10	12	12
Optics Housing	7	7	8	8
	17	17	20	20

Survival Heaters

	# of Primary Heater Circuits	# of Redundant Heater Circuits	# of Primary Thermostat s	# of Redundant Thermostats
MEB	2	2	4	4
MCEB	2	2	4	4
Digitizers	2	2	4	4
CCDs (on Thermal Sharing Plate)	1	1	2	2
Silicon PIN and Preamp Thermal Boxes	2	2	4	4
InGaAs PIN and Preamp Thermal Boxes	2	2	4	4
Singlet Preamp Thermal Boxes	2	2	4	4
Optics Housing	4	4	8	8
Scan Drum Motor / Encoder	1	1	2	2
Momentum Compensation Motor/Encoder	1	1	2	2
Momentum Compensation Wheel	1	1	2	2
Half Angle Mirror Assembly	1	1	2	2
Half Angle Mirror Motor / Encoder	1	1	2	2
Tilt Mechanism Motor 1/ Resolver	1	1	2	2
Tilt Mechanism Motor 2/Resolver	1	1	2	2
Calibration Target Stepper Motor / Resolver	1	1	2	2
	25	25	50	50

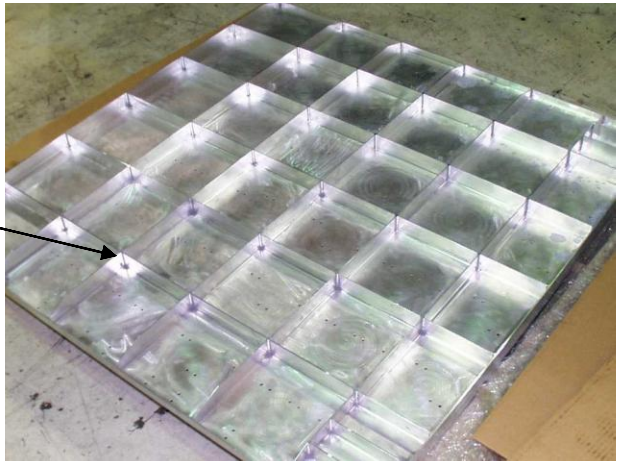
Radiator and Heater Power Sizing

- Radiators are sized in worst hot operating case
- Operating mode heater power is sized in worst cold operating case
- GSFC Gold Rules call for a maximum of 70% heater duty cycle for an active heater control thermal design
  - In sizing heater electrical resistance (R), orbital average heater power shall be no more than 70% of peak heater power (V**2/R)
    - Valid for both bang-bang and PID controllers

Radiator Area Reduction Option

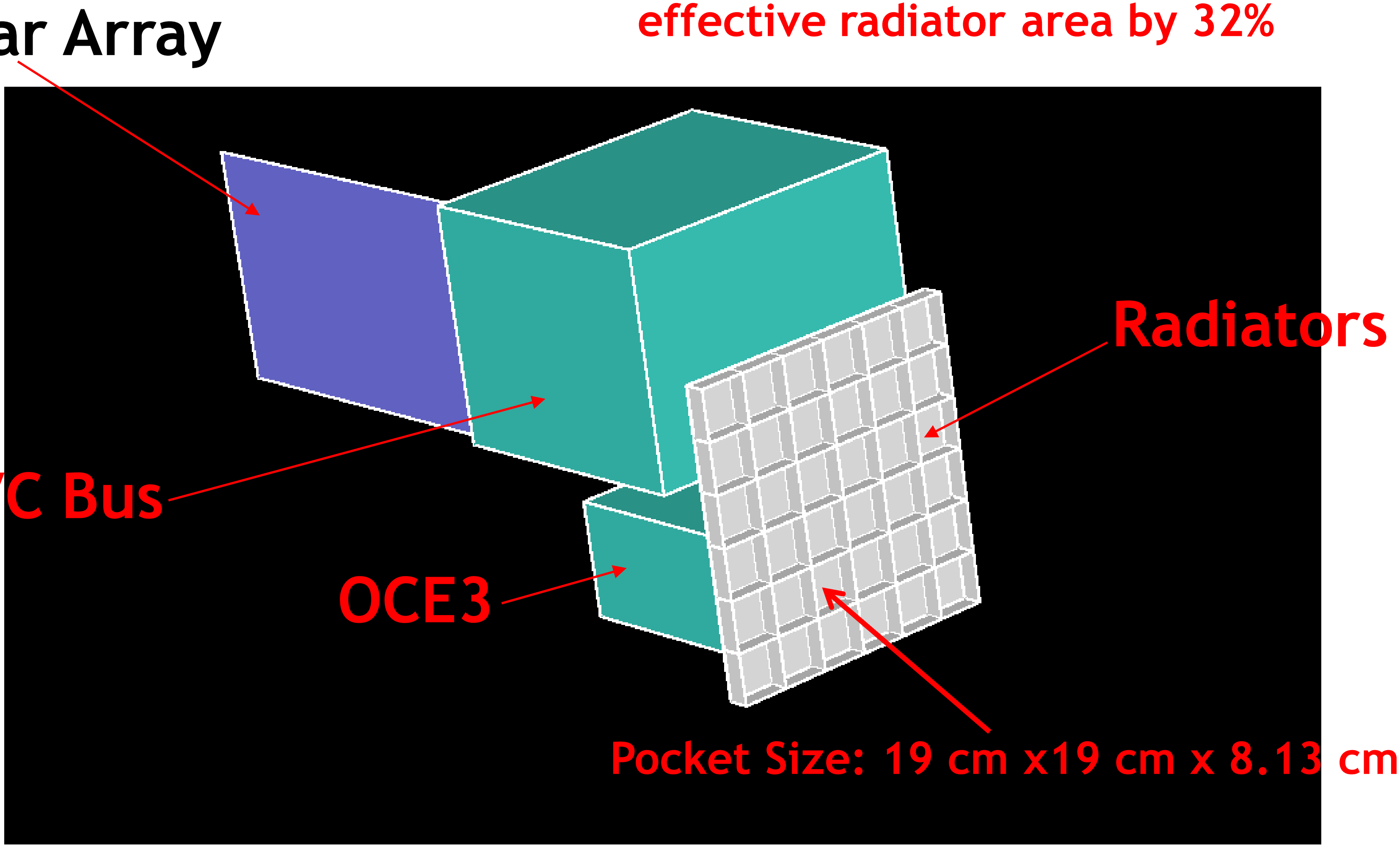
- **A radiator with grids is an option for reducing radiator footprint**
  - Flown on Swift BAT

Swift BAT
Radiator Prior to Paint
Application

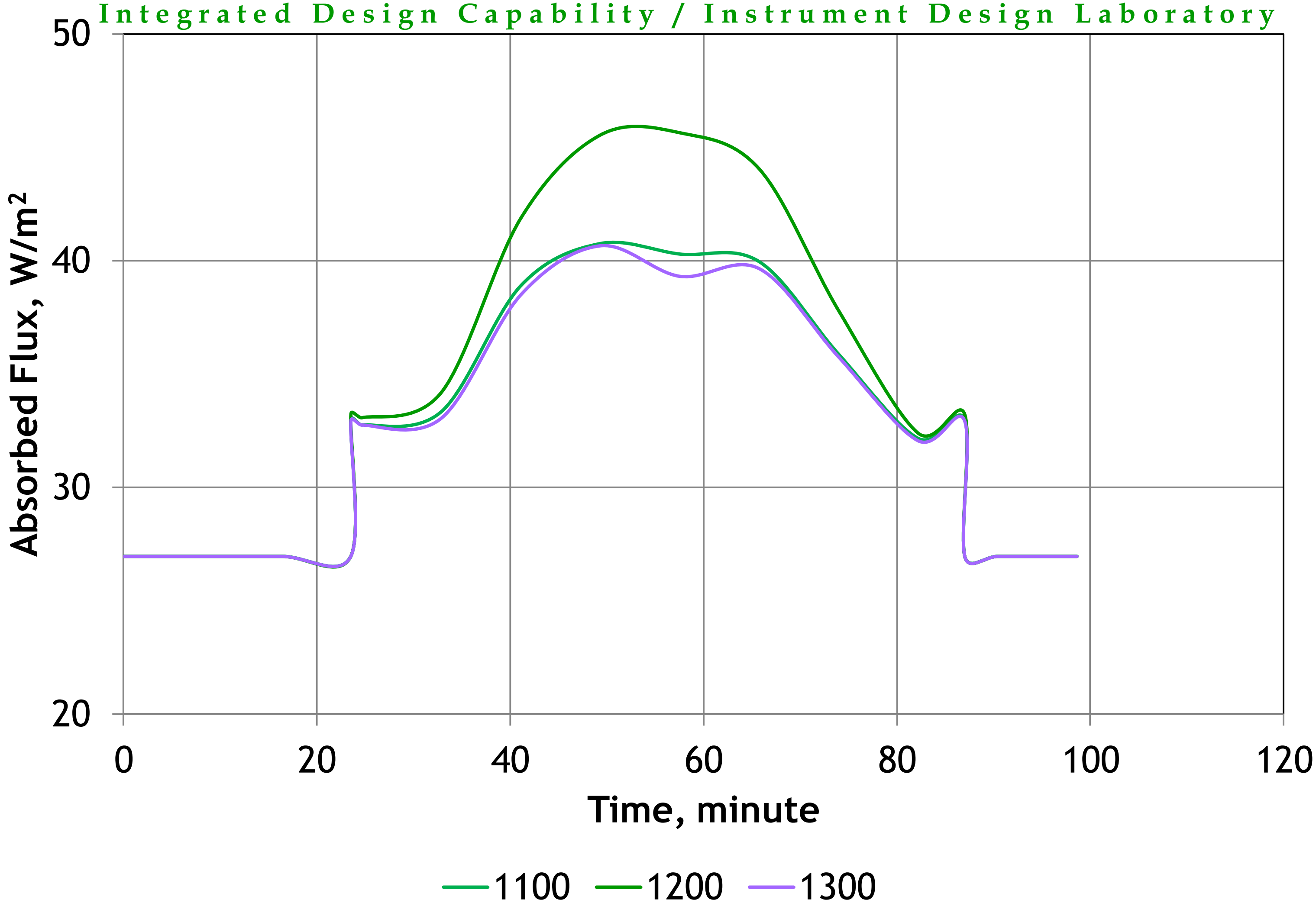


Thermal Model

Pocketed radiator increases effective radiator area by 32%



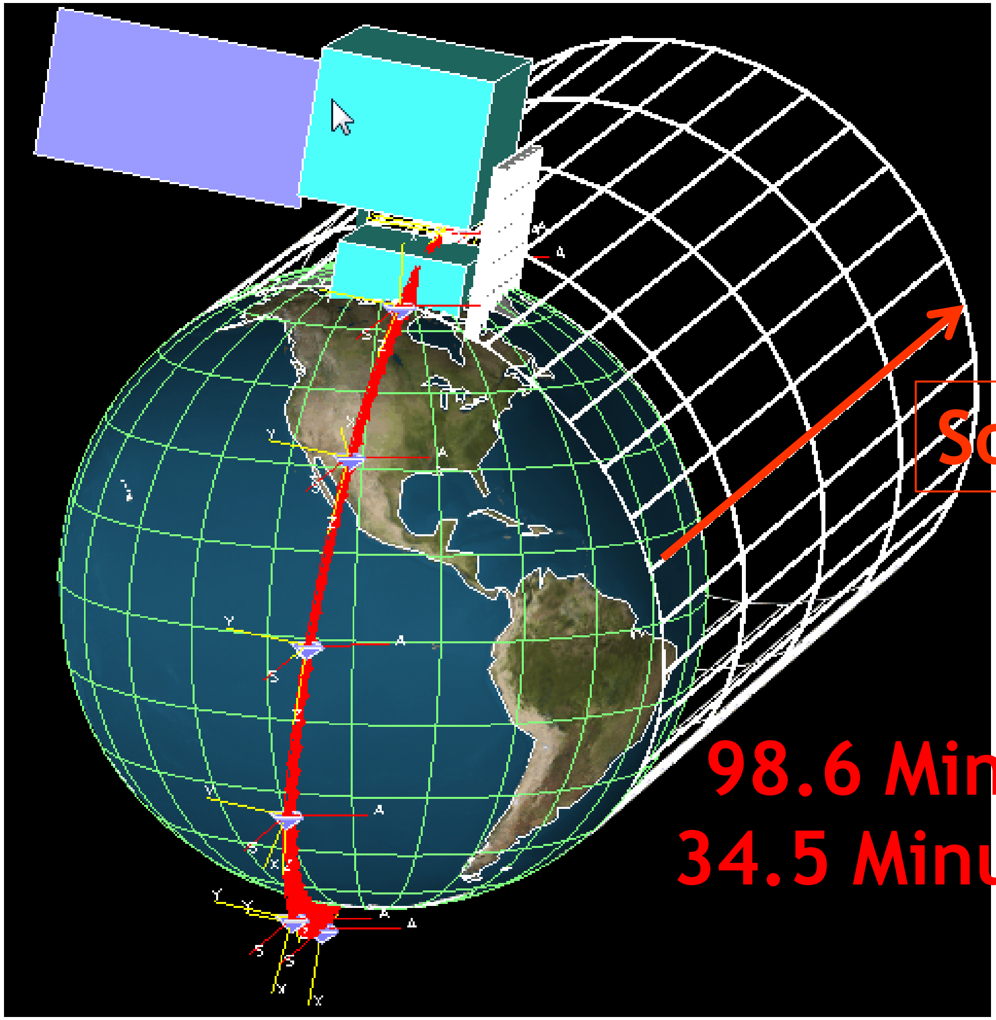
Effect of Equatorial Crossing Local Time on Radiator



Effect on radiator sizing is small

Thermal Model

1100 Equatorial Crossing, -17° Beta



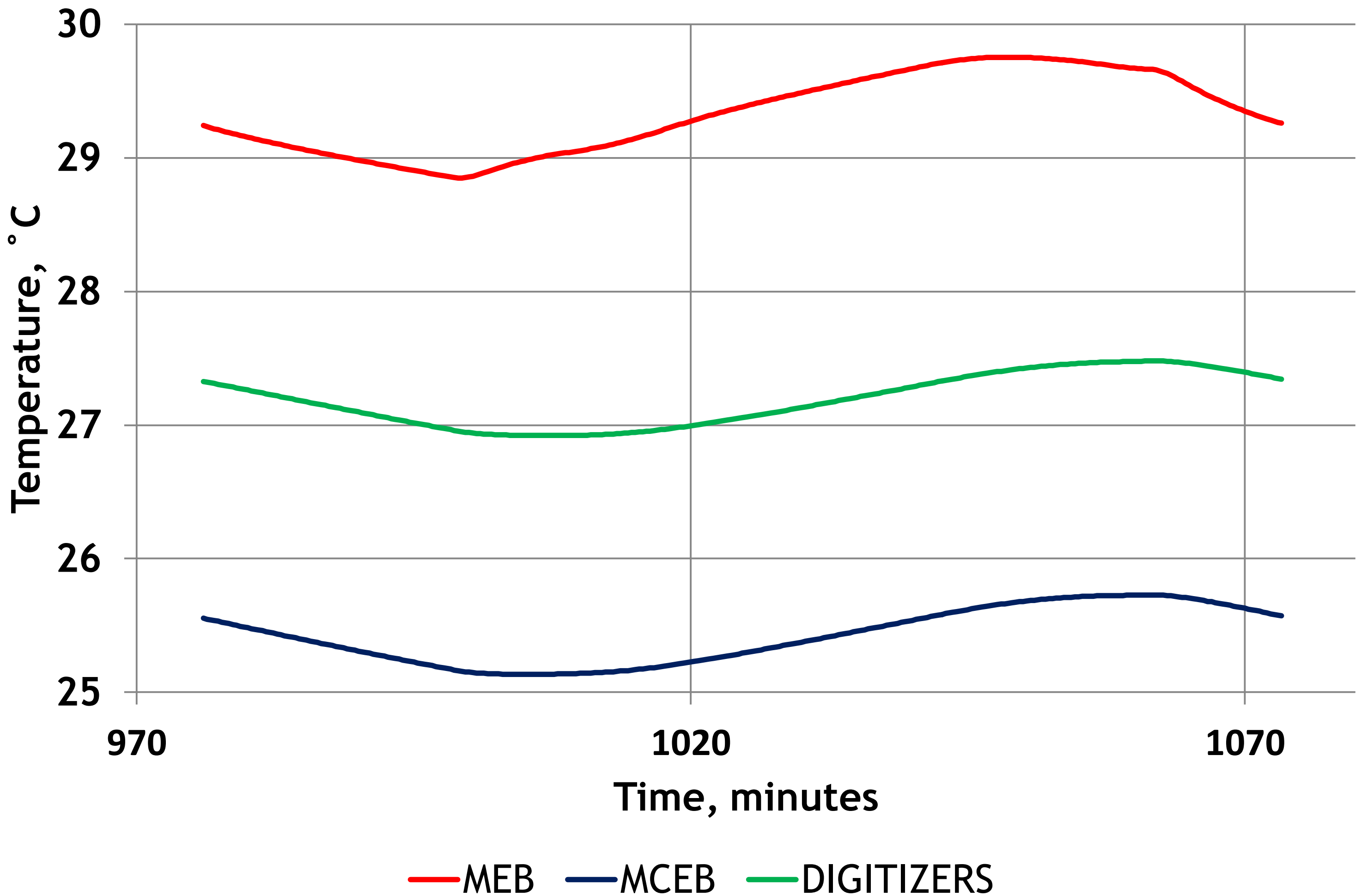
Spacecraft enlarged to show its orientation

Pocketed Radiator

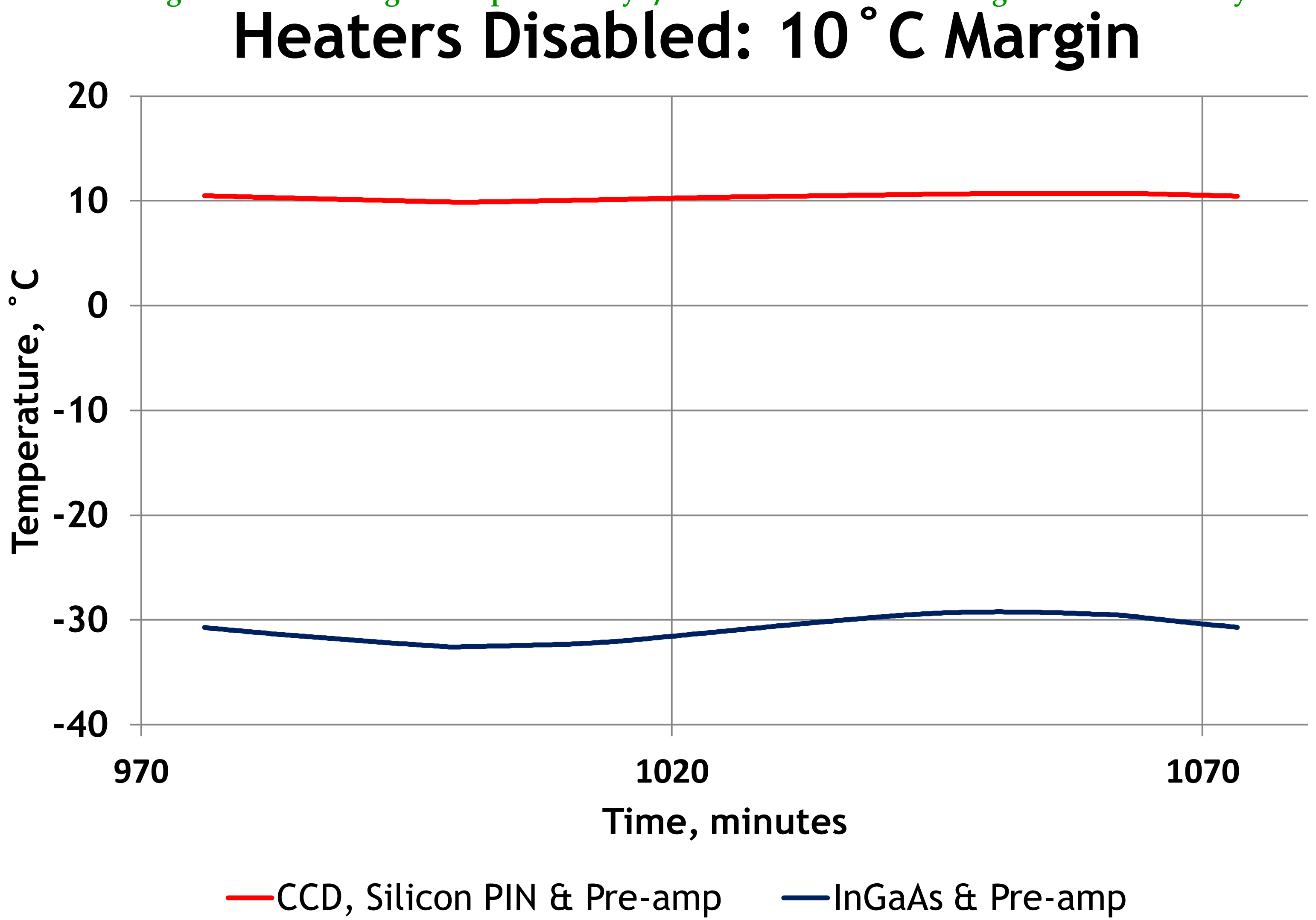
	Coating	Footprint Area (m^2)
CCD, Silicon PIN and Preamp	AZW-LA-II White Paint	0.089
InGaAs PIN and Preamp	AZW-LA-II White Paint	0.545
MEB, MCEB and Digitizers	AZW-LA-II White Paint	0.634
Total		1.269*

*OCE2 Delta study had 1.239 m^2

Worst Hot Case Thermal Predictions

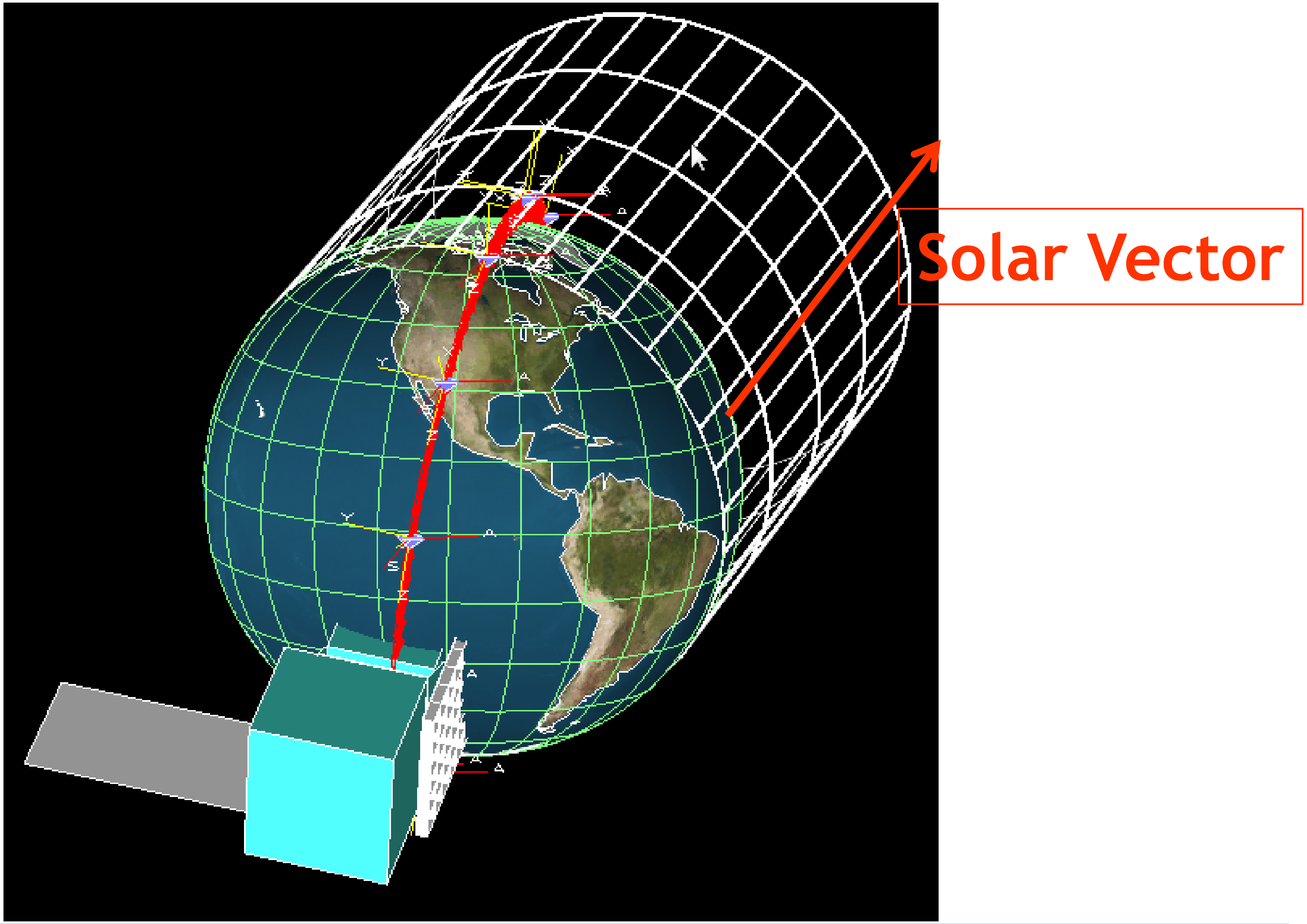


Worst Hot Case Thermal Predictions

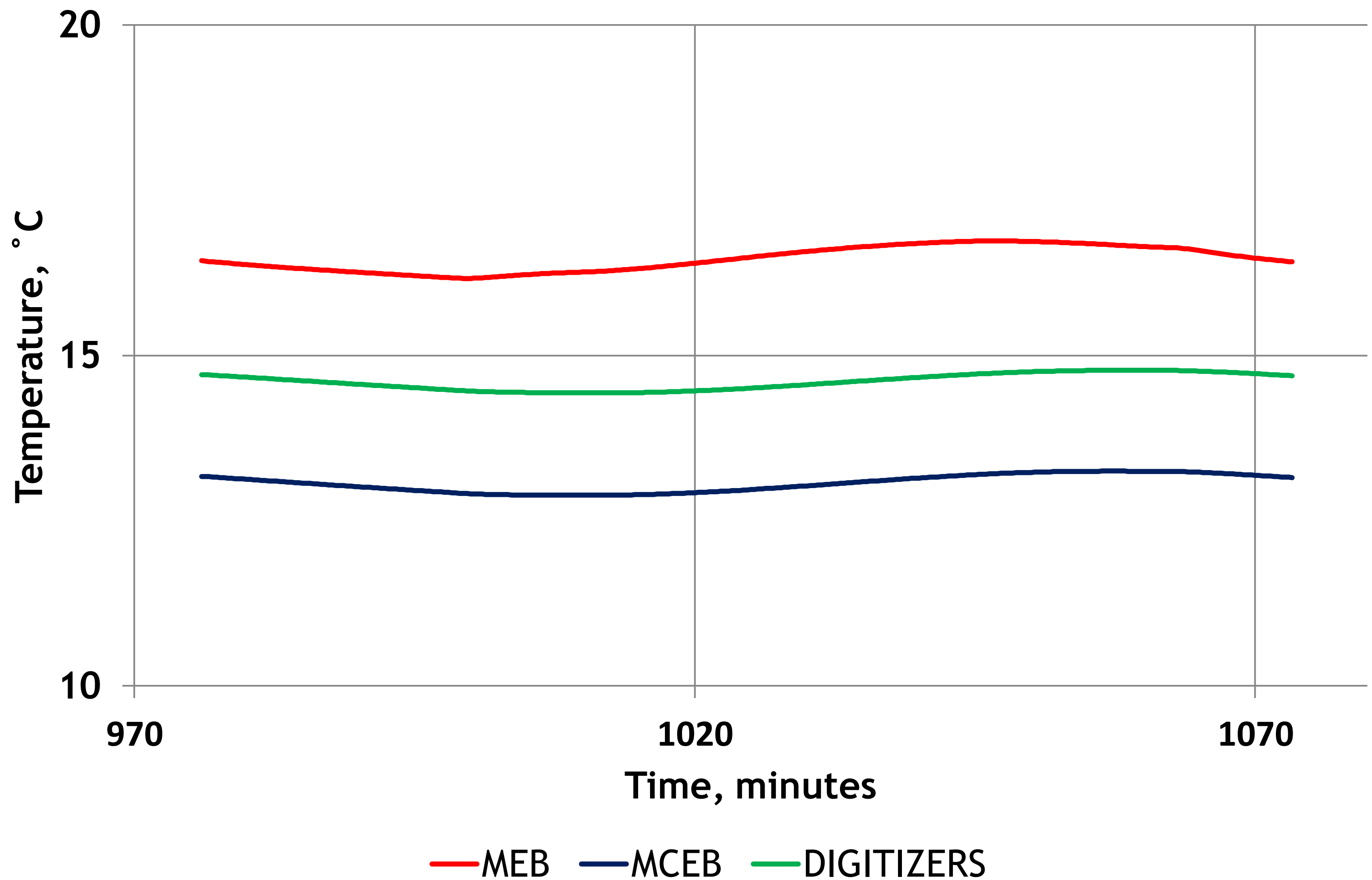


Worst Cold Case (Operating and Survival)

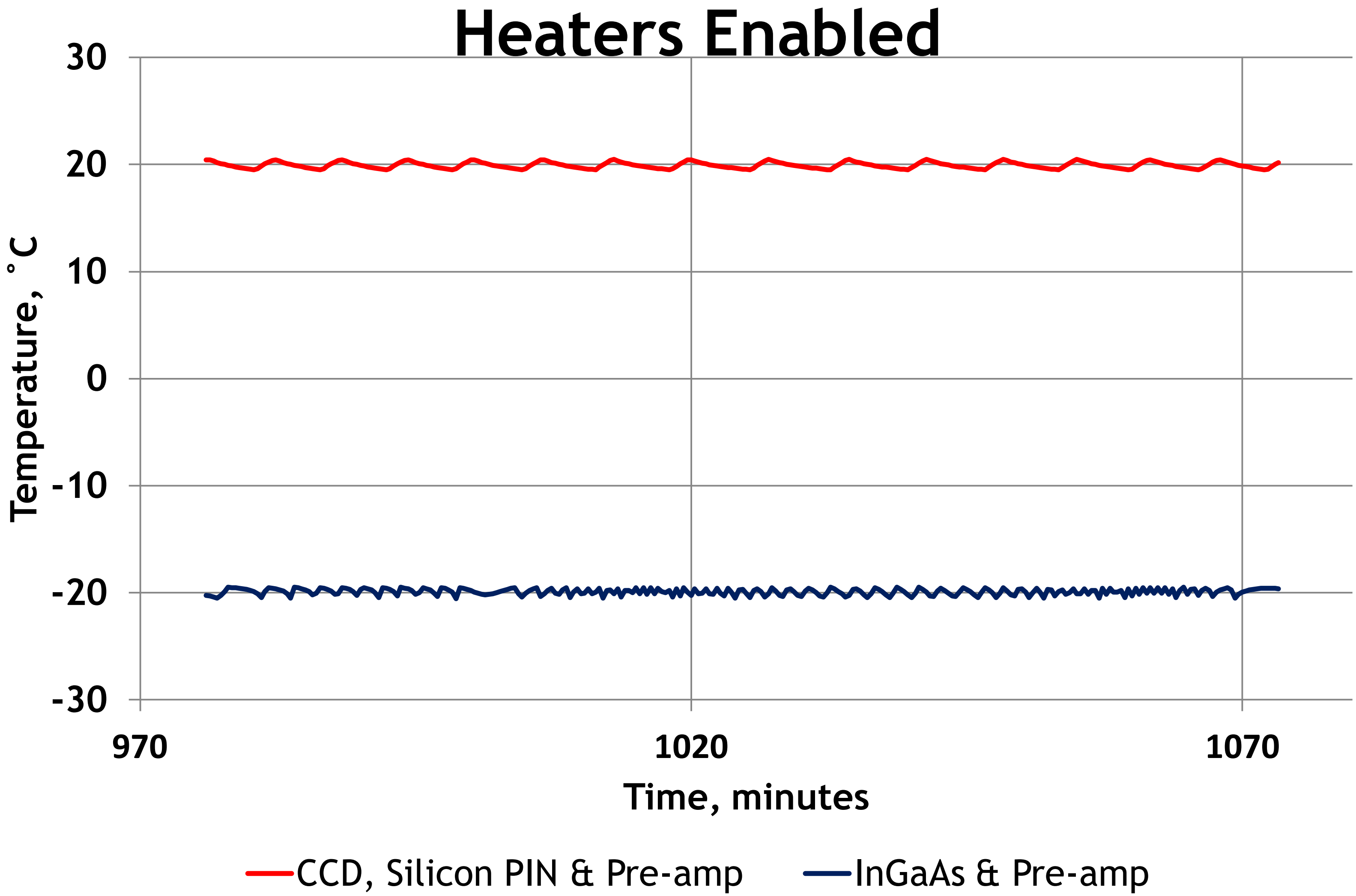
1100 Equatorial Crossing, -8° Beta



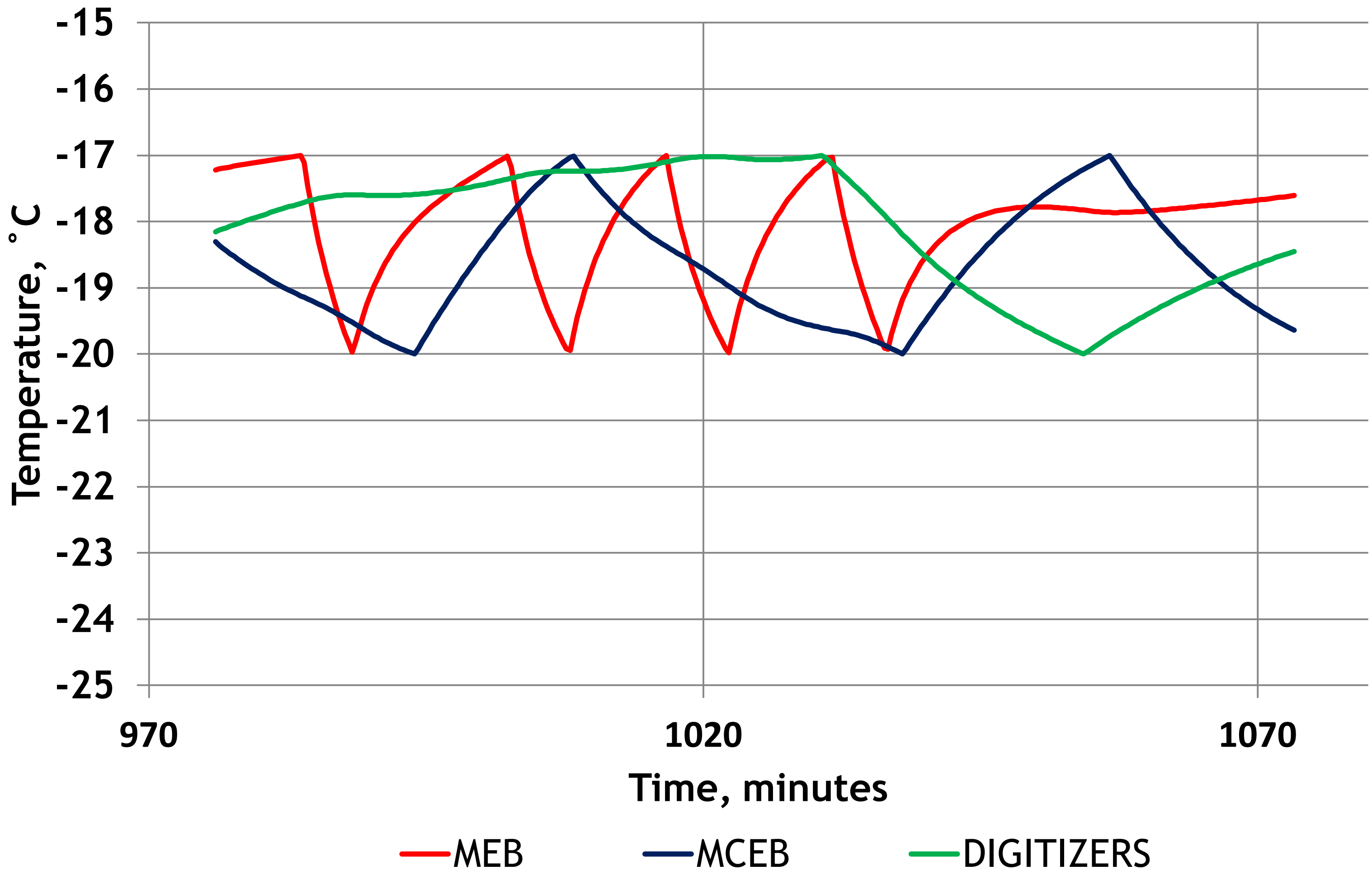
Worst Cold Case Thermal Predictions



Worst Cold Case Thermal Predictions

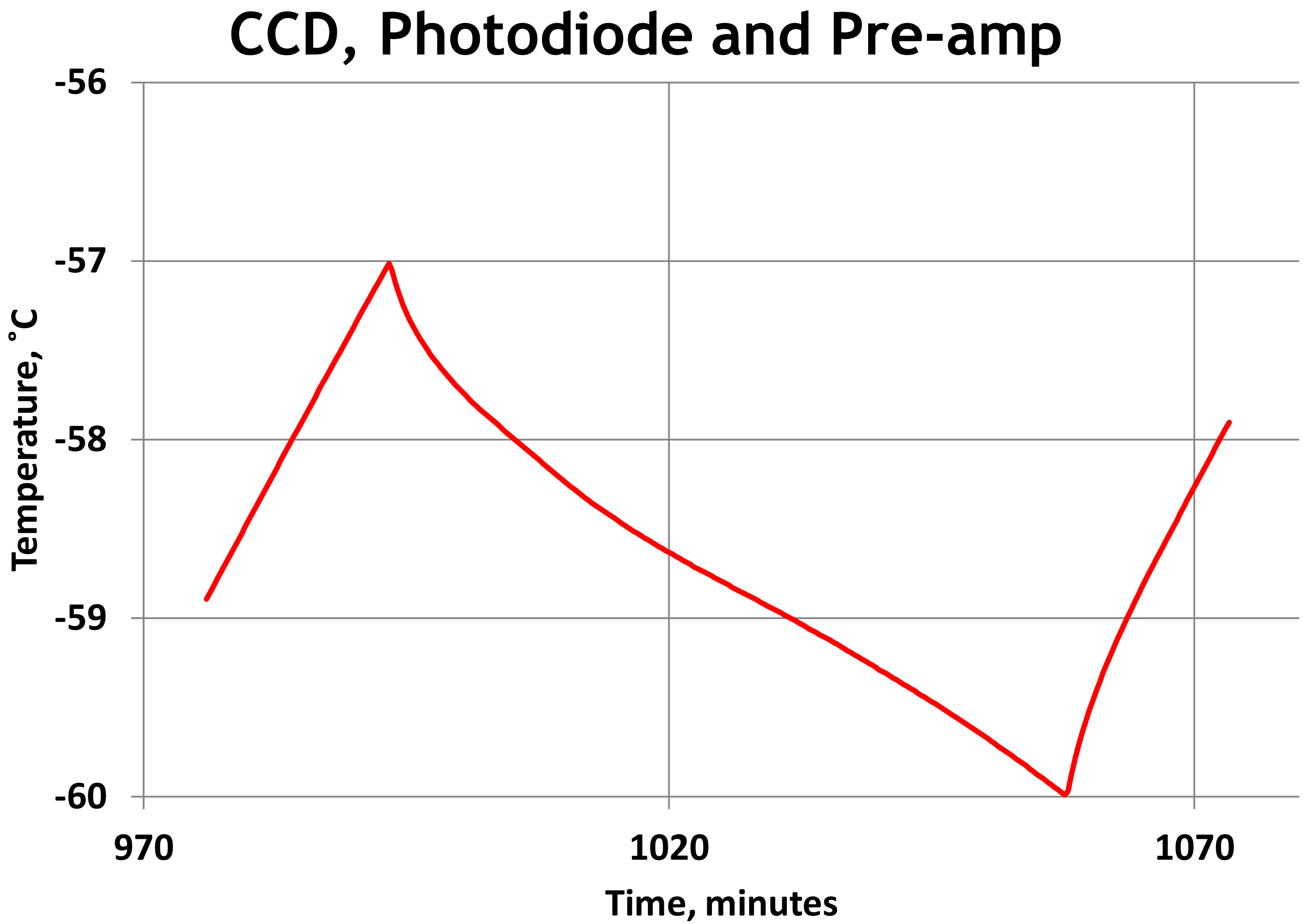


Worst Cold Survival Thermal Predictions*



*-8° beta angle science orbit

Worst Cold Survival Thermal Predictions



-8° beta angle science orbit

Operating Mode Heater Power

	Average Heater Power (W)	Peak Heater Power (W)
CCD, Silicon PIN & Preamp	13	19
InGaAs PIN & Preamp	37	53
Fiber Optics Enclosure	15	21
Optics Housing	10	14
	75	107

Survival Heater Power

	Average Heater Power (W)	Peak Heater Power (W)
MEB, MCEB and Digitizer	130	186
CCD, Silicon PIN & Preamp	7	10
InGaAs & Preamp	33	47
Fiber Optics Enclosure	14	20
Optics	10	14
Mechanisms	35	50
	229*	327

*Add 95 W if S/C points OCE3 radiators at space only so that no Earth flux impinges radiators.

Thermal System Mass Estimate (Pocketed Radiator)

Thermal Subsystem Components	Mass Ea (kg)	Qty	Mass Total (kg)	TRL
Ammonia CCHPs on Silicon PIN/Preamp Thermal Boxes (1 m; 1.27 cm diameter)	0.2	4	0.8	7
Ammonia CCHP Header for Silicon PIN/Preamp Thermal Boxes (3 m; 2.54 cm diameter)	1.2	2	2.4	7
Ammonia CCHPs on InGaAs/Preamp Thermal Boxes (2.2 m; 1.27 cm diameter)	0.44	1	0.44	7
Ammonia CCHP Header for InGaAs/Preamp Thermal Boxes (2 m; 2.54 cm diameter)	0.8	2	1.6	7
Ammonia CCHPs on MEB, MCEB and Digtizers (2.5 m; 2.54 cm diameter)	1	2	2	7
Silicon PIN/Preamp Radiator (0.0893 m2 footprint; 2.54 mm thick aluminum)	1.206	1	1.206	7
Silicon PIN/Preamp Radiator AZW-LA-II white paint (0.0893 m2 footprint)	0.133	1	0.133	9
InGaAs PIN/Preamp Radiator (0.545 m2 footprint; 2.54 mm thick aluminum)	7.371	1	7.371	7
InGaAs PIN/Preamp Radiator AZW-LA-II white paint (0.545 m2 footprint)	0.818	1	0.818	9
MEB, MCEB and Digtizer Radiator (0.634 m2 footprint; 2.54 mm thick aluminum)	8.574	1	8.574	7
MEB, MCEB and Digtizer Radiator AZW-LA-II white paint (0.634 m2 footprint)	0.951	1	0.951	9
Ammonia CCHP Spreaders on Silicon PIN/Preamp Radiator (1.2 m; 1.27 cm diameter)	0.24	2	0.48	7
Ammonia CCHP Spreaders on InGaAs PIN/Preamp Radiator (1.2 m; 1.27 cm diameter)	0.24	4	0.96	7
Ammonia CCHP Spreaders on MEB, MCEB & Digtizers Radiator (1.2 m; 1.27 cm diameter)	0.24	5	1.2	7
Copper straps for CCDs (3.8 cm x 7.62 cm x 0.508 cm)	0.132	3	0.396	7
Silicon PIN/Preamp Thermal Boxes (aluminum)	0.91	2	1.82	7
InGaAs/Preamp Thermal Boxes (aluminum)	0.91	2	1.82	7
CCD Thermal Sharing Plate (5.04 cm x 5.04 cm x 0.2 cm; aluminum)	0.14	1	0.14	7
AZ93 white paint on Drum Assembly/Telescope (1 m2)	0.15	1	0.15	9

Thermal System Mass Estimate (Pocketed Radiator)

Thermal Subsystem Components	Mass Ea (kg)	Qty	Mass Total (kg)	TRL
Z306 black paint on optics enclosure interior (1.121 m2)	0.17	1	0.17	9
Z306 black paint on and Drum Assembly/Telescope Interior (1 m2)	0.15	1	0.15	9
MLI -- Silicon PIN/Preamp Radiator backside (0.128 m2)	0.08	1	0.08	9
MLI -- InGaAs PIN/Preamp Radiator backside (0.545 m2)	0.327	1	0.327	9
MLI -- MEB, MCEB and Digtizer Radiator backside (0.634 m2)	0.38	1	0.38	9
MLI - Fiber Optics Enclosure, Thermal Boxes and CCHPs (5.5 m2)	3.3	1	3.3	9
MLI - Optics Enclosure (1.1 m2)	0.66	1	0.66	9
MLI - Detectors internal to Optics Enclosure (0.24 m2)	0.144	1	0.144	9
MLI - Cradle (1.45 m2)	0.87	1	0.87	9
MLI - MEB and MCEB (0.486 m2)	0.291	1	0.291	9
MLI - Digitizers (1.215 m2)	0.728	1	0.728	9
Velcro, buttons, adhesive, etc. for MLI	0.503	1	0.503	9
Op Heaters -- Kapton Film 5.1 cm x 6.4 cm	0.002	34	0.068	9
Thermostats (Op Heaters) -- Honeywell 3100 Series	0.006	40	0.24	9
Survival Heaters -- Kapton Film 5.1 cm x 6.4 cm	0.002	50	0.1	9
Thermostats (Survival Heaters) -- Honeywell 3100 Series	0.006	100	0.6	9
Thermistors/Platinum RTDs (Op heater control and telemetry)	0.001	60	0.06	9
Adhesive for Heaters, Thermostats and Thermistors and Al Tape for Heaters	0.15	1	0.15	9
Subtotal			42.08	

Other Thermal Components

Radiator Bracket Front = 1.44
Radiator Bracket Rear = 1.05
Mass of Thermal Spacer = 0.1
Total Mass = 44.67

Conclusion

- Thermally isolation between -20˚C components (InGaAs PIN/preamp, 3 singlet pre-amps), 20˚C components (silicon PIN/preamp, CCD, 3 singlet preamps), and 25˚C components (fiber optics and aft structure enclosure) is very important
- Radiators for InGaAs PIN/preamp, singlet pre-amp, silicon PIN/preamp, and CCD must rotate with these components because rigid CCHPs thermally couple them
- Radiator for electronics boxes must also rotate with these boxes because rigid CCHPs thermally couple them
- Rotating radiator consists of 3 segments, which are thermally isolated from each other, due to significant temperature differences

Conclusion cont'd

- Detector radiator area has no significant change from OCE2 despite total number (and power) of silicon PIN preamp and InGaAs preamp decreases to 69 from 174, because number of InGaAs preamp (-20˚C) increases to 48 from 6
- CCHPs are used to transfer heat from detectors, preamps and electronics boxes to radiators, and must be oriented properly to operate in reflux mode during ground testing
- A thermally favorable orientation in ground testing is to allow rotating radiator facing chamber roof so that radiator is higher than components
- Effect of equatorial crossing local time between 1100 and 1300 on radiator size is small

Conclusion cont'd

- Survival heater power of 230 W is for S/C nominal operating attitude and increases by 95 W if radiators point at cold space only and receive no Earth flux